U.S. FISH AND WILDLIFE SERVICE
SPECIES ASSESSMENT AND LISTING PRIORITY ASSIGNMENT FORM

SCIENTIFIC NAME: *Hypomesus transpacificus*

COMMON NAME: Delta smelt

LEAD REGION: Region 8

DATE INFORMATION CURRENT AS OF: May 15, 2013

STATUS/ACTION

__ Species assessment - determined either we do not have sufficient information on threats or the information on the threats does not support a proposal to list the species and, therefore, it was not elevated to Candidate status

___ Listed species petitioned for uplisting for which we have made a warranted-but-precluded finding for uplisting (this is part of the annual resubmitted petition finding)

___ Candidate that received funding for a proposed listing determination; assessment not updated

___ New candidate

_X__ Continuing candidate

___ Listing priority number change
Former LPN: _2__
New LPN: _2__

___ Candidate removal: Former LPN: ___

- ___ A – Taxon is more abundant or widespread than previously believed or not subject to the degree of threats sufficient to warrant issuance of a proposed listing or continuance of candidate status.
- ___U – Taxon not subject to the degree of threats sufficient to warrant issuance of a proposed listing or continuance of candidate status due, in part or totally, to conservation efforts that remove or reduce the threats to the species.
- ___ F – Range is no longer a U.S. territory.
- ___ I – Insufficient information exists on biological vulnerability and threats to support listing.
- ___ M – Taxon mistakenly included in past notice of review.
- ___ N – Taxon does not meet the Act's definition of "species."

___ X – Taxon believed to be extinct.

Date when the species first became a Candidate (as currently defined):

Petition Information:
___ Non-petitioned
_X__ Petitioned; Date petition received: 3-8-2006
90-day substantial finding FR publication date: 7-10-2008
12-month warranted but precluded finding FR publication date: 4-7-2010

FOR PETITIONED CANDIDATE SPECIES:
a. Is listing warranted (if yes, see summary of threats below)? Yes
b. To date, has publication of a proposal to list been precluded by other higher priority listing actions? Yes
c. Why is listing precluded? Higher priority listing actions, including court-approved settlements, court-ordered and statutory deadlines for petition findings and listing determinations, emergency listing determinations, and responses to litigation, continue to preclude the proposed and final listing rules for this species. We continue to monitor populations and will change its status or implement an emergency listing if necessary. The "Progress on Revising the Lists" section of the current CNOR (*http://endangered.fws.gov/*) provides information on listing actions taken during the last 12 months.

ANIMAL/PLANT GROUP AND FAMILY: Fish, Osmeridae

HISTORICAL STATES/TERRITORIES/COUNTRIES OF OCCURRENCE: Contra Costa, Sacramento, San Joaquin, Solano, and Yolo Counties in the state of California.

CURRENT STATES/COUNTIES/TERRITORIES/COUNTRIES OF OCCURRENCE: Contra Costa, Sacramento, San Joaquin, Solano, and Yolo Counties in the state of California.

LAND OWNERSHIP: This species occurs in open waters. There are no known land locked populations. The statutory Delta totals 738,000 acres including approximately 538,000 acres of agricultural land uses, 60,000 acres of open water, and 64,000 acres of urban land uses. The remainder of the region presently consists of open space and wildlife habitat.

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LEAD FIELD OFFICE CONTACT: Bay-Delta FWO, Colin Grant, 916-930-5651, colin_grant@fws.gov

BIOLOGICAL INFORMATION:

Species Description

Delta smelt are slender-bodied fish, generally about 60 to 70 millimeters (mm) (2 to 3 inches (in)) long, although they may reach lengths of up to 120 mm (4.7 in) (Moyle 2002, p. 227). Delta smelt are in the Osmeridae family (smelts) (Stanley et al. 1995, p. 390). Live fish are nearly translucent and have a steely blue sheen to their sides (Moyle 2002, p. 227). Delta smelt are also identifiable by their relatively large eye to head size. The eye can occupy approximately 25-30 percent of their head length (Moyle 2002, p. 227). Delta smelt have a small, translucent adipose fin located between the dorsal and caudal fins. Occasionally one chromatophore (a small dark spot) may be found between the mandibles, but most often there is none (Moyle 2002, p. 227).

Taxonomy

We have carefully reviewed the available taxonomic information to reach the conclusion that the delta smelt (*Hypomesus transpacificus)* is a valid taxon. The delta smelt is one of six species currently recognized in the *Hypomesus* genus (Bennett 2005, p. 8). Within the genus, delta smelt is most closely related to surf smelt (*H. pretiosis*), a species common along the western coast of North America. In contrast, delta smelt is a comparatively distant relation to the wakasagi (*H. nipponensis*), which was introduced into Central Valley reservoirs in 1959, and may be seasonally sympatric with delta smelt in the estuary (Trenham *et al.* 1998, p. 417). Allozyme studies have demonstrated that wakasagi and delta smelt are genetically distinct and presumably derived from different marine ancestors (Stanley *et al.* 1995, p. 394). Genetic characterization of delta smelt, longfin smelt, and wakasagi is presently under investigation, using contemporary methodologies. Delta smelt and longfin smelt hybrids have been observed in the Bay-Delta estuary (California Department of Fish and Game (CDFG) 2001, p. 473).

Habitat/Life History

Studies indicate that delta smelt require specific environmental conditions (freshwater flow, water quality) and habitat types within the estuary for migration, spawning, egg incubation, rearing, and larval and juvenile transport from spawning to rearing habitats (Moyle 2002, pp. 228–229). Delta smelt are a euryhaline (tolerate a wide range of salinities) species; however, they rarely occur in water with more than 10–12 parts per thousand salinity (about one-third seawater). Feyrer *at al.* (2007, p. 728) found that relative abundance of delta smelt was related to fall salinity and turbidity (water clarity). Delta smelt probably evolved within the naturally turbid (silt and particulate-laden) environment of the Delta and likely rely on certain levels of background turbidity at different life stages and for certain behaviors. Laboratory studies found that delta smelt larval feeding increased with increased turbidity (Baskerville-Bridges *et al.* 2004, p. 222).

Although spawning has not been observed in the wild, spawning location and timing has been inferred from the collection of larvae in sloughs and shallow edge-waters of channels in the upper Delta and in Montezuma Slough near Suisun Bay (Wang 1991, pp. 11–12). Spawning is believed to occur from late January through late June or early July at water temperatures ranging from 7 to 20 ^{0}C (44.6 to 71.6 ^{0}F) (Bennett 2005, p. 13; Wang 2007, p. 6). In the laboratory, spawning has been observed to occur between 12 and 22 ^{0}C (54 and 72 ^{0}F) (Bennett 2005, p. 13). In laboratory conditions, eggs typically hatch after 9 to 14 days and larvae begin feeding 5 to 6 days later (Mager *et al.* 2004, p. 172, Table 1). Larvae are generally most abundant in the Delta from mid-April through May (Bennett 2005, p. 13). After several weeks of development, larval surveys indicate that larvae move downstream until they reach nursery habitat in the “low salinity zone” (LSZ) where the salinity ranges from approximately .5 to 7 parts per thousand (ppt) (Kimmerer 1998, p. 1; Moyle 2002, p. 228; Dege and Brown 2004, pp. 57–58). Juvenile smelt rear and grow in the LSZ for several months, where they are found in relatively shallow open water (Dege and Brown 2004, pp. 56–58). In September or October, delta smelt reach adulthood and begin a gradual migration back into freshwater areas where spawning is thought to occur. Most delta smelt die after spawning, but a small contingent of adults survives and can spawn in their second year (Moyle 2002, p. 228).

Delta smelt feed primarily on small planktonic (free-floating) crustaceans, and occasionally on insect larvae (Moyle 2002, p. 228). Historically, the main prey of delta smelt was the copepod *Eurytemora affinis* and the mysid shrimp *Neomysis mercedis*. The slightly larger copepod *Pseudodiaptomus forbesi* has replaced *E. affinis* as a major prey source of delta smelt since its introduction into the San Francisco Bay-Delta. Two other copepod species, *Limnoithona tetraspina* and *Acartiella sinenisi*, have become abundant since their introduction to the San Francisco Bay-Delta in the mid-1990s. Delta smelt eat these introduced copepods, but *P. forbesi* remains a dominant prey item (Baxter *et al.* 2008, p. 22). The diets of larval delta smelt are limited to larval copepods (Nobriga 2002, p. 156). As mentioned previously, delta smelt are thought to require a turbid environment for efficient, successful foraging.

Currently available information indicates that delta smelt habitat is most suitable for the fish when low-salinity water is near 20 °C (68 °F), highly turbid, oxygen saturated, low in contaminants, and supports high densities of calanoid copepods and mysid shrimp (Lott 1998, pp. 14-19; Moyle 2002, p. 228; Nobriga 2002, pp. 160–163, Feyrer *et al.* 2007 pp. 728–732). Almost every component listed above has been degraded over time (see five factor analysis). We have determined that this accumulation of habitat change is the fundamental reason or mechanism that has caused delta smelt to decline. PBFs are described in further detail in the context of the threats analysis.

There have been documented changes to the delta smelt's low-salinity zone habitat that have led to present-day habitat conditions. The close association of delta smelt with the San Francisco estuary LSZ has been known for many years (Stevens and Miller 1983; Moyle *et al.* 1992). Reduced delta outflow causes the LSZ to move upstream, which concentrates delta smelt in a small area along with other competing planktivorous fishes (Bennett 2005, pp. 11, 20). Low freshwater outflows in the fall have been correlated with a reduced abundance index for young delta smelt the following summer (Feyrer *et al.* 2007, pp. 727–728).

Delta smelt are believed to require relatively turbid (not clear) waters to capture prey and avoid predators (Feyrer 2007, p. 731). From 1999 to present, the Delta has experienced a decline in turbidity that culminated in an estuary-wide step-decline in 1999 (Schoellhamer 2011, p. 897). Increased water clarity during the summer and fall has been shown to be negatively correlated with subsequent summer delta smelt abundance indices (Feyrer *et al.* 2007, p. 728; Nobriga *et al.* 2008, p. 8). Turbid waters are thought to increase foraging efficiency (Baskerville-Bridges *et al.* 2004, pp. 222–225) and reduce the risk of predation for delta smelt.

Temperature also affects delta smelt distribution. Delta smelt tolerate temperatures <7.5 to >25.4 ^{o}C (<45.5 to >77.7 °F) (Swanson 2000, p. 387), however warmer water temperatures >25 ^{o}C (77 °F) restrict their distribution more than colder water temperatures (Nobriga and Herbold 2008, p. 12). Delta smelt of all sizes are found in the main channels of the Delta and Suisun Marsh and the open waters of Suisun Bay where the waters are well oxygenated and temperatures are usually less than 25^{o} C (77 °F) in summer (Nobriga *et al.* 2008, pp. 9–11). Currently, delta smelt are subjected to thermally stressful temperatures every summer, and all available regional climate change projections predict central California will be warmer still in the coming decades (Cloern 2011, p. 7).

<u>Historical Range/Distribution</u>

The delta smelt historical range is thought to have extended from San Pablo Bay upstream to at least the city of Sacramento on the Sacramento River and the city of Mossdale on the San Joaquin River. They were once one of the most common pelagic (living in open water away from the bottom) fish in the upper Sacramento-San Joaquin Estuary (Moyle 2002, p. 230).

Current Range/Distribution

Delta smelt are endemic to (native and restricted to) the San Francisco Bay and Sacramento-San Joaquin Delta Estuary (Delta) in California, found only from the San Pablo Bay upstream through the Delta in Contra Costa, Sacramento, San Joaquin, Solano, and Yolo Counties (Moyle 2002, p. 227). Their historical range is thought to have extended from San Pablo Bay upstream to at least the city of Sacramento on the Sacramento River and the city of Mossdale on the San Joaquin River.

Population Estimates/Status

Within the Bay-Delta, delta smelt are consistently collected in the monitoring surveys that have been conducted by California Department of Fish and Wildlife, dating back to 1959. Most of the ongoing studies are currently lead by the Interagency Ecological Program (IEP), an entity made up of state, Federal- and non-government agencies that work collaboratively to oversee data collection and scientific analysis in the Bay-Delta. Several of the IEP's field investigations provide annual delta smelt abundance information, including the spring Kodiak trawl (SKT), the smelt larva survey (SLS), the 20mm survey (20mm), the summer townet survey (TNS), and the fall midwater trawl (FMWT). Relative abundance information can also be obtained from count data on delta smelt entrained into the Federal and state water export facilities.

The FMWT provides the best available long-term index of the relative abundance of delta smelt (Moyle *et al.* 1992; Sweetnam 1999). The indices derived from FMWT closely mirror trends in catch per unit effort (Kimmerer and Nobriga 2005), but do not, at present, support statistically reliable population abundance estimates, though substantial progress has recently been made (Newman 2008). FMWT-derived data are generally accepted as providing a reasonable basis for detecting and roughly scaling interannual trends in delta smelt abundance. The FMWT-derived indices have ranged from a low of 17 in 2009 to 1,673 in 1970 (Figure). For comparison, TNS-derived indices have ranged from a low of 0.3 in 2005 and 2009 to a high of 62.5 in 1978 (Figure). Although the peak high and low values have occurred in different years, the FMWT and TNS indices show a similar pattern of delta smelt relative abundance that is higher prior to the mid-1980s and very low in the past decade.

From 1969–1981, the mean delta smelt FMWT and TNS and indices were 894 and 22.5, respectively. Both indices suggest the delta smelt population declined abruptly in the early 1980s (Moyle *et al.* 1992). From 1982-1992, the mean delta smelt FMWT and TNS indices dropped to 272 and 3.2, respectively. The population rebounded somewhat in the mid–1990s (Sweetnam 1999); the mean FMWT and TNS indices were 529 and 7.1, respectively, during the 1993–2002 period. From 2003–2012, the FMWT and TNS index averaged 83.3 and 1.04, which is the lowest decade on record. Delta smelt numbers have trended precipitously downward since the early 2000s. In the wet water year of 2011, the FMWT index for Delta smelt increased to 343, which is the highest index recorded since 2001. Despite this increase, the overall trend for delta smelt abundance is still downward.

FIGURE 1: Delta smelt abundance (total across year-classes) as indexed by the Fall Mid-Water Trawl of the Bay-Delta, 1967–2012.

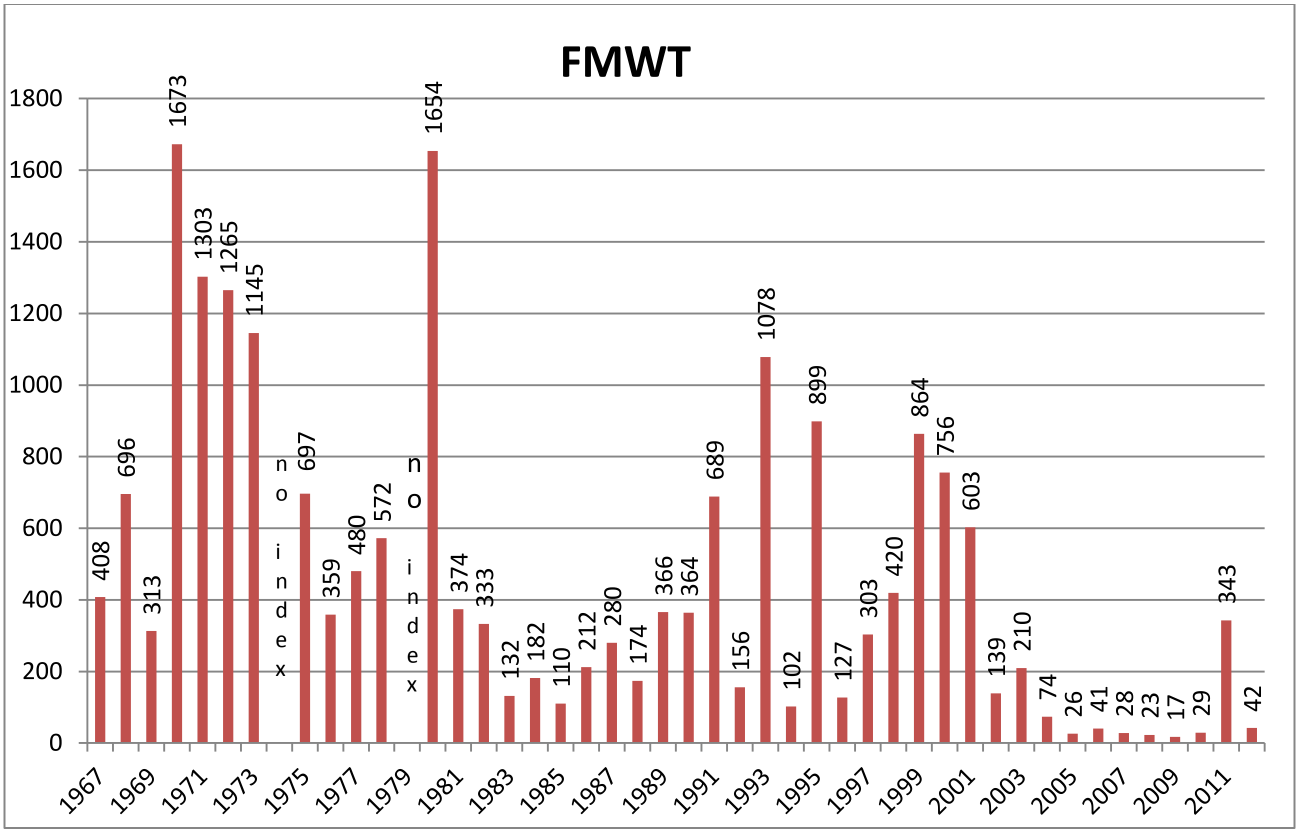
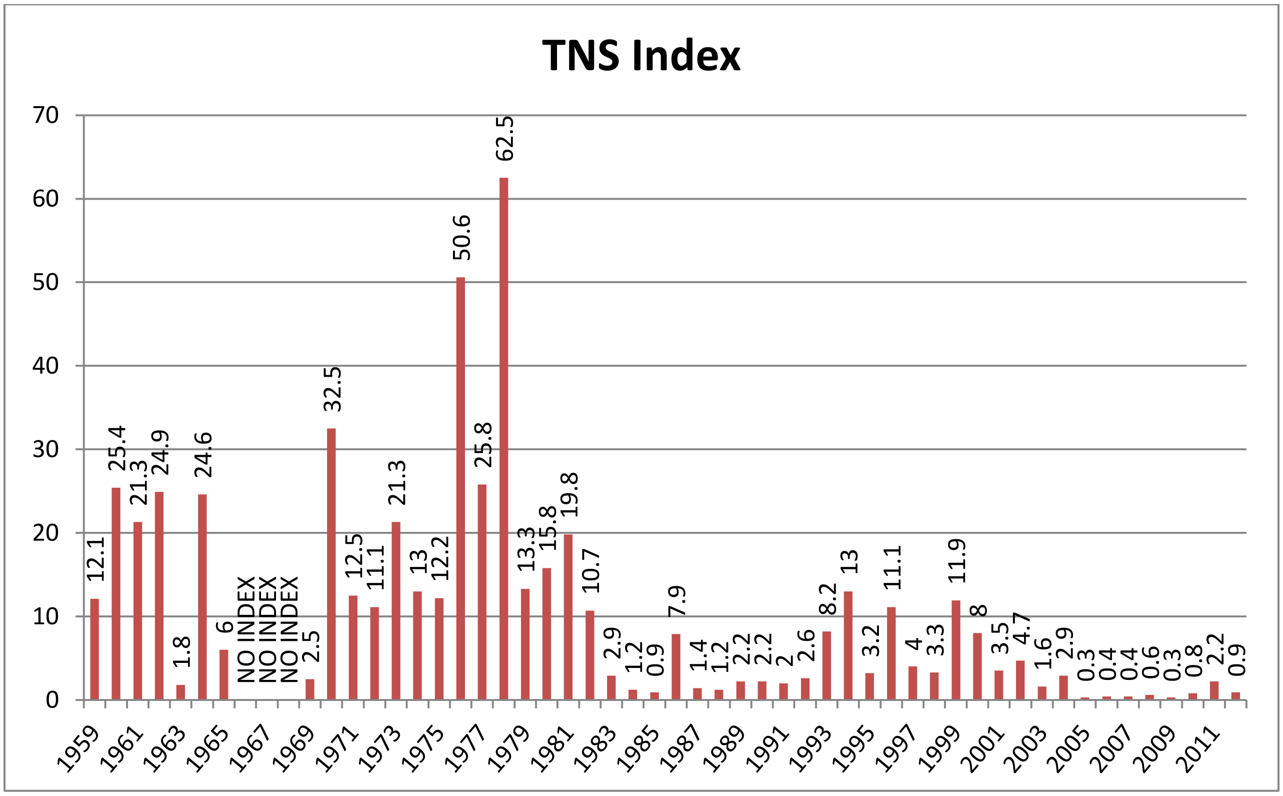


FIGURE 2: Summer Townet Survey index 1959–2012: The summer townet survey shows a decline in the population over time remaining below an index of one for seven of the last eight years.



DISTINCT POPULATION SEGMENT (DPS)

SIGNIFICANT PORTION OF THE RANGE (SPR)

THREATS

A. <u>The present or threatened destruction, modification, or curtailment of its habitat or range</u>.

Reduced Freshwater Flow

From late spring through fall and early winter, delta smelt occur in the low-salinity zone (LSZ), whose geographic location varies with Delta water outflow (Dege and Brown 2004, pp. 56-58; USFWS 2008, pp. 147, 150). Reduced Delta outflow causes the LSZ to move upstream, which concentrates delta smelt in a small area along with other competing planktivorous fishes (Bennett 2005, pp. 11, 20). Causes of such reduced outflows include changes in timing and volume of releases from upstream dams, delta water exports at the State and Federal diversion facilities, and upstream water diversions (Feyrer *et al.* 2007, p. 731; USFWS 2008, p. 153). Low freshwater outflows in the fall have been correlated with a reduced abundance index for young delta smelt the following summer (Feyrer *et al.* 2007, pp. 727, 728).

As California's population has grown, demands for reliable water supplies and flood protection have grown. In response, State and Federal agencies built dams and canals, and captured water in reservoirs, to increase capacity for water storage and conveyance resulting in one of the largest manmade water systems in the world (Nichols *et al.* 1986, p. 569). Operation of this system has altered the seasonal pattern of freshwater flows in the watershed. Storage in the upper watershed of peak runoff and release of the captured water for irrigation and urban needs during subsequent low flow periods result in a broader, flatter hydrograph with less seasonal variability in freshwater flows into the estuary (Kimmerer 2004, p. 15).

In addition to the system of dams and canals built throughout the Sacramento River-San Joaquin River basin, the Bay-Delta is unique in having a large water diversion system located within the estuary (Kimmerer 2002b, p. 1279). The State Water Project (SWP) and Central Valley Project (CVP) operate two water export facilities in the Delta (Sommer *et al*. 2007, p. 272). Project operation and management is dependent upon upstream water supply and export area demands. Despite the size of the water storage and diversion projects, much of the interannual variability in Delta hydrology is due to variability in precipitation from year to year. Annual inflow from the watershed to the Delta is strongly correlated to unimpaired flow (runoff that would hypothetically occur if upstream dams and diversions were not in existence), mainly due to the effects of high-flow events (Kimmerer 2004, p. 15). Water operations are regulated in part by the California State Water Resources Control Board (SWRCB) according to the Water Quality Control Plan (WQCP) (SWRCB 2000, entire). The WQCP limits Delta water exports in relation to Delta inflow (the Export/Inflow, or E/I ratio).

It is important to note that in the case of the Bay-Delta, freshwater flow is expressed as both Delta inflow (from the rivers into the Delta) and as Delta outflow (from the Delta into the lower estuary), which are closely correlated, but not equivalent. Freshwater flow affects the location of the two-parts-per-thousand salinity isohaline (X2, indexed as distance in kilometers from the Golden Gate Bridge). The location of X2 is influenced by precipitation in the watershed (i.e., wetter or drier seasonal weather patterns) and by water operations both upstream at the dams and diversions, and in the Delta at the water export facilities (Jassby *et al*. 1995; Kimmerer 2004). Because X2 integrates many physical attributes over time and space, many Bay-Delta organisms respond to it, making it a useful indicator of habitat conditions (Jassby *et al*. 1995; Dege and Brown 2004). Along with seasonality and export volume, X2 may be an indicator of the risk of entrainment (Jassby *et al*. 1995; USFWS 2008; Grimaldo *et al*. 2009).

The population is strongly influenced by river flows because the quantity of fresh water flowing through the estuary changes the amount and location of suitable low-salinity, open-water habitat (Feyrer *et al*. 2007 pp. 728–732; Nobriga and Herbold 2008, p. 11). X2 has been shown to be positively correlated with both delta smelt habitat and delta smelt abundance (Feyrer *et al.*, 2011, p. 124). Optimal Delta smelt habitat increases by approximately two fold when the location of X2 moves from 85 km to 70 km (Feyrer *et al.*, p. 23). When X2 is located downstream of the confluence at 80 km, the area of suitable habitat is increased encompassing the areas of Suisun and Grizzly Bays (Feyrer *et al.*, p. 24). In winters with high Delta outflow, the spawning range of delta smelt shifts west to include the Napa River (Hobbs *et al.* 2007, p. 524). Fish inhabiting

Suisun Marsh and the Sacramento-San Joaquin River confluence may also spawn near their rearing habitat when water quality conditions enable them (i.e., when flows increase and fresher water moves over these seasonally brackish rearing habitats). Furthermore, the lower the Delta outflow, the higher the proportion of the young delta smelt population that overlaps the array of irrigation diversions in the Delta (Kimmerer and Nobriga 2008, pp. 19–20).

In addition to the effects of reduced freshwater flow on habitat suitability for delta smelt and other organisms in the Bay-Delta, one of the principal concerns over the biological impacts of these water export facilities has been entrainment of fish and other aquatic organisms. For a detailed discussion, see Factor E: Entrainment Losses, below.

Climate Change

Our analyses under the Endangered Species Act include consideration of ongoing and projected changes in climate. The terms "climate" and "climate change" are defined by the Intergovernmental Panel on Climate Change (IPCC). The term "climate" refers to the mean and variability of different types of weather conditions over time, with 30 years being a typical period for such measurements, although shorter or longer periods also may be used (IPCC 2007a, p. 78). The term "climate change" thus refers to a change in the mean or variability of one or more measures of climate (e.g., temperature or precipitation) that persists for an extended period, typically decades or longer, whether the change is due to natural variability, human activity, or both (IPCC 2007a, p. 78).

Scientific measurements spanning several decades demonstrate that changes in climate are occurring, and that the rate of change has been faster since the 1950s. Examples include warming of the global climate system, and substantial increases in precipitation in some regions of the world and decreases in other regions. (For these and other examples, see IPCC 2007a, p. 30; and Solomon *et al*. 2007, pp. 35–54, 82–85). Results of scientific analyses presented by the IPCC show that most of the observed increase in global average temperature since the mid-20th century cannot be explained by natural variability in climate, and is "very likely" (defined by the IPCC as 90 percent or higher probability) due to the observed increase in greenhouse gas (GHG) concentrations in the atmosphere as a result of human activities, particularly carbon dioxide emissions from use of fossil fuels (IPCC 2007a, pp. 5-6 and figures SPM.3 and SPM.4; Solomon *et al*. 2007, pp. 21–35). Further confirmation of the role of GHGs comes from analyses by Huber and Knutti (2011, p. 4), who concluded it is extremely likely that approximately 75 percent of global warming since 1950 has been caused by human activities.

Scientists use a variety of climate models, which include consideration of natural processes and variability, as well as various scenarios of potential levels and timing of GHG emissions, to evaluate the causes of changes already observed and to project future changes in temperature and other climate conditions (e.g., Meehl *et al*. 2007, entire; Ganguly *et al*. 2009, pp. 11555, 15558; Prinn *et al*. 2011, pp. 527, 529). All combinations of models and emissions scenarios yield very similar projections of increases in the most common measure of climate change, average global surface temperature (commonly known as global warming), until about 2030. Although projections of the magnitude and rate of warming differ after about 2030, the overall trajectory of all the projections is one of increased global warming through the end of this century, even for the projections based on scenarios that assume that GHG emissions will stabilize or decline.

Thus, there is strong scientific support for projections that warming will continue through the 21st century, and that the magnitude and rate of change will be influenced substantially by the extent of GHG emissions (IPCC 2007a, pp. 44–45; Meehl *et al*. 2007, pp. 760–764 and 797–811; Ganguly *et al*. 2009, pp. 1555515558; Prinn *et al*. 2011, pp. 527, 529). (See IPCC 2007b, p. 8, for a summary of other global projections of climate-related changes, such as frequency of heat waves and changes in precipitation. Also see IPCC 2011(entire) for a summary of observations and projections of extreme climate events.)

Various changes in climate may have direct or indirect effects on species. These effects may be positive, neutral, or negative, and they may change over time, depending on the species and other relevant considerations, such as interactions of climate with other variables (e.g., habitat fragmentation) (IPCC 2007, pp. 8–14, 18–19). Identifying likely effects often involves aspects of climate change vulnerability analysis. Vulnerability refers to the degree to which a species (or system) is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the type, magnitude, and rate of climate change and variation to which a species is exposed, its sensitivity, and its adaptive capacity (IPCC 2007a, p. 89; see also Glick *et al.* 2011, pp. 19–22). There is no single method for conducting such analyses that applies to all situations (Glick *et al.* 2011, p. 3). We use our expert judgment and appropriate analytical approaches to weigh relevant information, including uncertainty, in our consideration of various aspects of climate change.

Global climate projections are informative, and, in some cases, the only or the best scientific information available for us to use. However, projected changes in climate and related impacts can vary substantially across and within different regions of the world (e.g., IPCC 2007a, pp. 8–12). Therefore, we use "downscaled" projections when they are available and have been developed through appropriate scientific procedures, because such projections provide higher resolution information that is more relevant to spatial scales used for analyses of a given species (see Glick *et al*. 2011, pp. 58–61, for a discussion of downscaling). With regard to our analysis for the Delta smelt, downscaled projections are available.

The effects of climate change do not act in isolation, but act in combination with existing threats to species and systems. We considered the potential effects of climate change on the Delta smelt based on projections derived from various modeling scenarios. Temperature increases are likely to lead to a continued rise in sea level, further increasing salinity within delta smelt habitat and likely shifting spawning and early rearing upstream as the boundary of fresh and brackish water moves upstream. Reduced snowpack, earlier melting of the snowpack, and increased water temperatures will likely alter freshwater flows, possibly shifting and condensing the timing of delta smelt spawning (See Freshwater Flow above).

San Francisco Bay-Delta Climate Change

Effects of climate change could be particularly profound for aquatic ecosystems and include increased water temperatures and altered hydrology, along with changes in the extent, frequency, and magnitude of extreme events such as droughts, floods, and wildfires (Reiman and Isaak 2010, p. 1). Numerous climate models predict changes in precipitation frequency and pattern in the western United States (IPCC 2007b, p. 8). Projections indicate that temperature and precipitation changes will diminish snowpack, changing the availability of natural water supplies

(USBR 2011, p. 143). Warming may result in more precipitation falling as rain and less storage as snow. This would result in increased rain on snow events and increase winter runoff as spring runoff decreases (USBR 2011, p. 147). Earlier seasonal warming increases the likelihood of rain-on-snow events, which are associated with mid-winter floods. Smaller snowpacks that melt earlier in the year result in increased drought frequency and severity (Rieman and Isaak 2010, p. 6). These changes may lead to increased flood and drought risk during the 21st century (USBR 2011, p. 149).

It is uncertain how a change in the timing and duration of freshwater flows will affect delta smelt. The melting of the snowpack earlier in the year could result in higher flows in January and February, ahead of peak spawning and hatching months for delta smelt. This could alter the timing or magnitude of migration and spawning cues, and potentially result in decreased spawning success. As the freshwater boundary moves farther inland into the Delta with increasing sea level (see below) and reduced flows, adults will need to migrate farther into the Delta to spawn, increasing the risk of predation and the potential for entrainment into water export facilities and diversions for both themselves and their progeny.

We evaluated different projections of sea level rise to estimate future climate effects on ashy storm-petrel nesting habitat. The National Academy of Sciences (NAS) projected that sea levels along the California coast south of Cape Mendocino will rise 4–30 centimeters (cm) (2–12 inches (in)) by 2030, 12–61 cm (5–24 in) by 2050, and 42–167 cm (16–66 in) by 2100 (NAS 2012, p. 131) compared to 2000 sea levels. Research indicates that the coastal land area south of Cape Mendocino is sinking at an average rate of about 1 millimeter (mm) (.04 in) per year, although Global Positioning System (GPS)-measured rates vary widely (-3.7–0.6 mm per year) (NAS 2012, p. 93). The NAS committee used output from global ocean models under an IPCC (2007) mid-range greenhouse gas emission scenario (NAS 2012, p. 5). However, carbon dioxide emissions from fossil fuels for the past decade have been at the high end of IPCC scenarios owing to rapid economic growth in developing countries (Le Qu´er´e *et al.* 2009). Because emissions for the last decade have been on the high end of the IPCC scenarios, a maximum rise of 5.48 feet (ft) (167 cm) by 2100 is appropriate for analyzing the impact of sea level rise on delta smelt.

Even if emissions could be halted today, the oceans would continue to rise and expand for centuries due to their capacity to store heat (CEC 2009, pp. 49–50). In the Bay-Delta, higher tides combined with more severe drought and flooding events are likely to increase the likelihood of levee failure, possibly resulting in major alterations of the environmental conditions (Moyle 2008, pp. 362–363). It is reasonable to conclude that more severe drought and flooding events will also occur in other estuaries where the Delta smelt occurs. Sea level rise is likely to increase the frequency and range of saltwater intrusion. Salinity within the northern San Francisco Bay is projected to rise by 4.5 psu by the end of the century (Cloern *et al*. 2011, p. 7). Elevated salinity levels could push the position of X2 farther up the estuary and could result in increased distances that delta smelt must migrate to reach spawning habitats. Fall X2 mean values are projected to increase by a mean of about 7 km to the area of Antioch for a distance of approximately 90 km from the golden gate bridge by 2100 (Brown *et al.* 2013, no pagination). This increase in the position of X2 is expected to result in a decrease in suitable physical habitat (Brown *et al.* 2013, no pagination). Elevated sea levels could result in greater sedimentation, erosion, coastal flooding, and permanent inundation of low-lying natural ecosystems (CDFG 2009, p. 30).

We expect warmer estuary temperatures to be yet another significant conservation challenge based on climate change models. Typically, the bulk of delta smelt spawning occurs at water temperatures between 7 and 15 °C (44.6 and 59 °F), although spawning has been observed at both lower and higher temperatures (Wang 1986, p., Moyle 2002, p. 229). Mean annual water temperatures within the upper Sacramento River portion of the Bay-Delta estuary are expected to approach or exceed 14 °C (57.2 °F) during the second half of this century (Cloern *et al.* 2011, p. 7). Warmer water temperatures could increase delta smelt mortality and constrict suitable habitat throughout the Delta during the summer months. Due to warming temperatures, Delta smelt are projected to spawn between ten and twenty-five days earlier in the season depending on the location (Brown *et al.* 2013, no pagination). Also due to expected temperature increases, total number of high mortality days is expected to increase for all IPCC climate change scenarios (Brown *et al.*, no pagination). The number of stress days is expected to be stable or decrease partly because many stress days will become high mortality days. This could lead to delta smelt being forced to grow under highly stressful conditions during summer and fall with less time to mature because of advanced spawning (Brown *et al.* 2013, p.). Higher temperatures would shrink delta smelt distribution into the fall, limiting their presence to Suisun Bay and in waters with less than optimal salinities (Brown *et al.* 2013, p.). Water temperatures are presently above 20°C (68 °F) for most of the summer in core habitat areas (Figure 8), sometimes even exceeding the nominal lethal limit of 25 °C (77 °F) for short periods.

Turbidity

Delta smelt are believed to require relatively turbid (not clear) waters to capture prey and avoid predators (Feyrer 2007, p. 731). From 1999 to present, the Delta has experienced a decline in turbidity that culminated in an estuary-wide step-decline in 1999 (Schoellhamer 2011, p. 897). Increased water clarity during the summer and fall has been shown to be negatively correlated with subsequent summer delta smelt abundance indices (Feyrer *et al.* 2007, p. 728; Nobriga *et al.* 2008, p. 8). The increased water clarity in delta smelt rearing habitat in recent decades is attributed to the interruption of sediment transport by upstream dams (Arthur and Ball 1979, p. 157; Wright and Schoellhamer 2004, pp. 7, 10) and the spread of the exotic invasive water plant *Egeria densa* (Brazilian waterweed), which traps suspended sediments (Feyrer *et al.* 2007, p. 731). The likelihood of delta smelt occurrence in trawls at a given sampling station decreases with increasing Secchi depth at the stations (Feyrer *et al.* 2007, p. 728, Nobriga *et al.* 2008, p. 9). This is consistent with behavioral observations of captive delta smelt (Nobriga and Herbold 2008, p.11). Few daylight trawls catch delta smelt at Secchi depths over one half meter and capture probabilities for delta smelt are highest at 0.40 m depth or less. Since 1978, delta smelt have become increasingly rare in summer and fall surveys of the San Joaquin region of the San Francisco Bay–Delta (Nobriga *et al.* 2008, p. 9). The primary reason appears to be the comparatively high water clarity in the region, although high water temperatures are also likely a contributing factor (Nobriga *et al.* 2008, pp. 8, 9). Turbid waters are thought to increase foraging efficiency (Baskerville-Bridges *et al.* 2004, pp. 22–25) and reduce the risk of predation for delta smelt.

Channel Disturbances

Channel maintenance dredging occurs regularly within the Bay-Delta and other estuaries that serve as shipping channels (e.g., Humboldt Bay, Coos Bay, Yaquina Bay, Columbia River). Ongoing maintenance dredging and other channel disturbances potentially degrade spawning habitat and cause entrainment loss of individual fish and eggs; disposal of dredge spoils also can create large sediment plumes that expose fish to gill-clogging sediments and possibly to decreased oxygen availability (Levine-Fricke 2004, p. 56). Dredging can change the light transmittance, dissolved oxygen, nutrients, salinity, temperature and pH of the water (Navy 1990, entire). Dredging will re-suspend contaminants if they are present in the surface sediments (Levine-Fricke 2004, p. 44). Dredging can result in entrainment, injury or displacement (particularly in marinas) of delta smelt (Levine-Fricke 2004, p. 67–72). Individual delta smelt are likely most vulnerable to entrainment by dredging during spawning and egg incubation because eggs are deposited and develop on channel bottom substrates (Levine-Fricke, p. 69). Eggs laid that are not directly taken by dredging activities may remain unfertilized or could become covered by silt stirred up by dredging operations and suffocated (USACE 1999, p. 26). Sand mining does occur in Delta smelt habitat, but has been reduced in recent years (Barnard 2012, S. 9) although this trend will likely not continue as demand for sand is partly controlled by road and other construction demands. Because spawning substrate is not limited for the species, loss of sand is not expected to result in a decline of the species. We have found no information documenting population impacts of maintenance dredging on delta smelt.

Based on a review of the best scientific and commercial information available, we find that destruction, modification, or curtailment of habitat poses a threat to delta smelt. The operation of upstream reservoirs, increased water exports, and upstream water diversions has altered the location and extent of the low salinity zone. Upstream reservoirs and the increased presence of *Egeria densa* have also reduced turbidity levels in rearing habitat, which may reduce foraging efficiency. Rising water temperatures and increased salinity in the Delta due to climate change may reduce delta smelt habitat in the future.

B. Overutilization for commercial, recreational, scientific, or educational purposes.

Delta smelt monitoring surveys are conducted throughout the year, including the Fall Mid-Winter Trawl (FMWT), Summer Townet Survey (TNS), 20-mm Survey, and Spring Kodiak Trawl Survey (SKT). Overall take by survey collection is believed to be low compared to estimated relative abundances (Bennett 2005, p. 7); however, considering the concern for reduced abundance based on trend assessment, questions arise as to whether these and other surveys pose a concern to the delta smelt. An average of 2527 delta smelt adults and 968 delta smelt larvae and juveniles were taken each year by 23 different surveys between 2005 –2012 (Souza 2013, unpublished data). Because of low abundance and a high level of sampling mortality, survey methods have been modified to minimize potential impacts to delta smelt (K. Souza 2009, pers. comm.). Based on the low number of delta smelt collected in sampling surveys and the modified methods employed to further reduce these collections, we find that the amount of take expected to occur from sampling surveys does not reach a level substantial enough to be considered a threat. There is no evidence of use of the species for other commercial, recreational, scientific, or educational purposes.

Based on a review of the best scientific information available, we find that overutilization for commercial, recreational, scientific or educational purposes is not a threat to the delta smelt.

C. Disease or predation.

Disease

Studies have not found evidence of significant disease infestations in wild delta smelt (Teh 2007, p. 8; Baxter *et al.* 2008, p. 14) (See contaminants discussion in Factor E for more information). Based on the best scientific and commercial information available, we conclude that disease is not a threat to the delta smelt.

Predation

At least three species of nonnative fish with the potential to prey on delta smelt occur within the Delta: Striped bass (*Morone saxatilis*), largemouth bass (*Micropterus salmoides*), and Mississippi silversides (*Menidia beryllina*) (Bennett 2005, p. 49; Baxter *et al.* 2008, p. 17). Striped bass are widely distributed in pelagic areas of the San Francisco Bay–Delta, and thus have wide areas of overlap with delta smelt juveniles and adults. They also tend to aggregate in the vicinity of water diversion structures, where delta smelt are frequently entrained (Nobriga and Feyrer 2007, p. 9). Thus, striped bass are likely to be the most significant predator of delta smelt (Nobriga and Feyrer 2007, p. 9), although the rarity of delta smelt would presumably make them a relatively unusual prey item. Delta smelt are not commonly found as prey for striped bass (Bennett 2005, p. 49; Nobriga and Feyrer 2007, p. 9); however, smelt may be taken opportunistically since both striped and largemouth bass have highly diverse diets (Nobriga and Feyrer 2007, p. 6).

Largemouth bass are freshwater fish that prefer shoreline (littoral) habitat with relatively dense water plants (Nobriga and Feyrer 2007, pp. 4, 8; Baxter *et al.* 2008, p. 17). Increases in the Delta's largemouth bass population since the early 1990s is believed to have been facilitated by the spread of the invasive plant *Egeria densa*, which provides bass habitat (Baxter *et al.* 2008, p. 17). Despite increases in largemouth bass populations and habitat, Nobriga and Feyrer (2007, p 6) did not find delta smelt as largemouth bass prey.

Mississippi silversides may be predators and competitors with delta smelt (Bennett 2005, pp. 49, 50). Mississippi silversides were first introduced to the San Francisco Bay–Delta in the mid-1970s, and have increased dramatically in numbers since the mid-1980s. They forage in schools around the shoreline habitats of the San Francisco Bay–Delta, where delta smelt larvae and eggs occur. They readily consume delta smelt larvae in aquarium tests. Bennett (2005, p. 50) concluded that "delta smelt are at high risk if eggs or larvae co-occur with schools of foraging silversides." We have no information regarding the extent to which this is likely to occur in the wild.

Based on a review of the best available scientific and commercial information, we find that predation likely constitutes a low-to-moderate threat. Although we have no empirical evidence to indicate predation has significantly increased since the time of listing, other factors, such increasing water clarity, could increase the risk of predation.

D. The inadequacy of existing regulatory mechanisms.

State Laws

California Endangered Species Act: The delta smelt was listed as threatened under the California Endangered Species Act (CESA) in 1993 (CDFG 2008, p. 5), and was reclassified as endangered under the CESA in 2010 (14 CCR 670.5). The CESA prohibits unpermitted possession, purchase, sale, or take of listed species. However, the CESA definition of take does not include harm, which under the Act can include destruction of habitat that actually kills or injures wildlife by significantly impairing essential behavioral patterns (50 CFR 17.3). The CESA does require consultation between the California Department of Fish and Game (CDFG) and other State agencies to ensure that activities of State agencies will not jeopardize the continued existence of State-listed species (CERES 2009, p. 1).

Porter Cologne Water Quality Control Act: The Porter-Cologne Water Quality Control Act (California Water Code 13000 *et seq.*) is a California State law that establishes the State Water Resources Control Board (SWRCB) and nine Regional Water Quality Control Boards that are responsible for the regulation of activities and factors that could degrade California water quality and for the allocation of surface water rights (California Water Code Division 7). In 1995, the SWRCB developed the Bay-Delta Water Quality Control Plan that established water quality objectives for the Delta. This plan is currently implemented by Water Rights Decision 1641, which imposes flow and water quality standards on State and Federal water export facilities to assure protection of beneficial uses in the Delta (USFWS 2008, pp. 21–27). The various flow objectives and export restraints were designed, in part, to protect fisheries. These objectives include specific freshwater flow requirements throughout the year, specific water export restraints in the spring, and water export limits based on a percentage of estuary inflow throughout the year. The water quality objectives were designed to protect agricultural, municipal, industrial, and fishery uses; they vary throughout the year and by the wetness of the year. In addition to regulating flow requirements, the Porter Cologne Water Quality Control Act also regulates contaminants released into the delta (see Clean Water Act).

Federal Laws

National Environmental Policy Act: The National Environmental Policy Act (NEPA) (42 U.S.C. 4321 *et seq.*) requires all Federal agencies to formally document, consider, and publicly disclose the environmental impacts of major Federal actions and management decisions significantly affecting the human environment. NEPA documentation is provided in an environmental impact statement, an environmental assessment, or a categorical exclusion, and may be subject to administrative or judicial appeal. However, the Federal agency is not required to select an alternative having the least significant environmental impacts, and may select an action that will adversely affect sensitive species provided that these effects are known and identified in a NEPA document. Therefore, we do not consider the NEPA process in itself to be a regulatory mechanism that is certain to provide significant protection for the delta smelt.

Endangered Species Act: The delta smelt is currently listed as a threatened species under the Endangered Species Act of 1973, as amended (Act). By general regulation under sections 4(d) and 7(a) of the Act, threatened fish or wildlife species are afforded all the regulatory protections that endangered fish or wildlife species have. However, in order to provide those measures necessary and advisable for the conservation of a species listed as threatened, we can issue a special rule under section 4(d) of the Act to allow different restrictions on "take" as defined in section 3(19) of the Act and regulated under section 9 of the Act. No special rules for delta smelt currently exist. The Act defines a "threatened species" as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range" (section 3(20) of the Act). An "endangered species" is "any species which is in danger of extinction throughout all or a significant portion of its range" (section 3(6) of the Act). Section 6 of the Act authorizes us to enter into conservation agreements with States, and to allocate funds for conservation programs to benefit threatened or endangered species. Neither section 6 of the Act nor Service policy gives higher priority to endangered vs. threatened species for conservation funding.

The Central Valley Project (CVP), operated by the Bureau of Reclamation (Reclamation), and State Water Project (SWP), operated by the California Resources Agency Department of Water Resources (DWR), are currently operating under a Biological Opinion (BO) issued December 15, 2008, under section 7 of the Act (Service 2008, pp. 1–396). The BO includes a reasonable and prudent alternative (RPA), according to which water export facility operations could proceed without jeopardizing the continued existence of the species or destroying or adversely modifying its designated critical habitat. It also includes an incidental take statement (ITS) specifying reasonable and prudent measures necessary to minimize the incidental take of the species resulting from CVP and SWP operations. Reclamation has accepted the RPA provisionally, but may decide to reinitiate consultation (Reclamation 2008, p. 1). The ITS and BO replace a previous ITS and BO issued in 2005 (Service 2005, p. 1), and also replace flow restrictions instituted by the District Court in the case of *NRDC* v. *Kempthorne* (Wanger 2007, pp. 1–11), which found the 2005 BO inadequate to conserve the species.

Central Valley Project Improvement Act:

The Central Valley Project Improvement Act amends the previous Central Valley Project authorizations to include fish and wildlife protection, restoration, and mitigation as project purposes having equal priority with irrigation and domestic uses, and fish and wildlife enhancement as having an equal priority with power generation. Included in CVPIA section 3406 (b)(2) was a provision to dedicate 800,000 acre-feet of Central Valley Project yield annually (referred to as "(b)(2) water") for fish, wildlife, and habitat restoration. Since 1993, (b)(2) water has been used and supplemented with acquired environmental water (Environmental Water Account and CVPIA section 3406 (b)(3) water) to increase stream flows and reduce

Central Valley Project export pumping in the Delta. These management actions were taken to contribute to the CVPIA salmonid population doubling goals and to protect delta smelt and their habitat (Guinee 2011, pers. comm.). As discussed above (under Biology and Factor A), increased freshwater flows have been shown to be beneficial to delta smelt.

Clean Water Act: The Clean Water Act (CWA) provides the basis for the National Pollutant Discharge Elimination System (NPDES). The CWA gives the EPA the authority to set effluent limits and requires any entity discharging pollutants to obtain a NPDES permit. The EPA is authorized through the CWA to delegate the authority to issue NPDES Permits to State governments. In States that have been authorized to implement CWA programs, the EPA still retains oversight responsibilities (EPA 2011, p. 1). California is one of these States to which the EPA has delegated CWA authority. The Porter-Cologne Water Quality Control Act established the California State Water Resources Control Board (SWRCB) and nine Regional Water Quality Control Boards that are now responsible for issuing these NPDES permits, including permits for the discharge of effluents such as ammonia. The SWRCB is responsible for regulating activities and factors that could degrade California water quality (California Water Code Division 7, section 13370-13389).

The release of ammonia into the estuary is having detrimental effects on the Delta ecosystem and food chain (see Factor E, below). There is currently no TMDL in place for ammonia discharge into the Sacramento watershed. The release of ammonia is controlled primarily by the CWA (Federal law) and secondarily through the Porter-Cologne Water Quality Control Act (State law). EPA is currently updating freshwater discharge criteria that will include new limits on ammonia (EPA 2009, pp. 1-46). An NPDES permit for the Sacramento Regional Wastewater Treatment Plant, a major discharger, was prepared by the California Central Valley Regional Water Quality Control Board in the fall of 2010, with new ammonia limitations intended to reduce loadings to the Delta. The new ammonia limits will take effect in 2020. Until that time, CWA protections for delta smelt are limited, and do not reduce the current threat to delta smelt.

Summary for Factor D

The continued decline in delta smelt abundance suggests that existing regulatory mechanisms, as currently implemented, are not adequate to reduce threats to the species. Therefore, based on a review of the best scientific information available, we find existing regulatory mechanisms are either not sufficient or may not be addressing the most significant threat to the species.

E. Other natural or manmade factors affecting its continued existence.

Other factors affecting the continued existence of the delta smelt include direct entrainment into water diversions, introduced species, contaminants, and increased vulnerabilities of small populations.

Agricultural Diversions for Irrigation: Water is diverted at numerous sites throughout the Bay-Delta for agricultural irrigation. Herren and Kawasaki (2001) reported over 2,200 such water diversions within the Delta, but CDFG (2009, p. 25) notes that number may be high because

Herren and Kawasaki (2001) did not accurately distinguish intake siphons and pumps from discharge pipes. CALFED's Ecosystem Restoration Program (ERP) includes a program to screen remaining unscreened small agricultural diversions in the Delta and the Sacramento and San Joaquin Rivers. The purpose of screening fish diversions is to prevent entrainment losses; however, very little information is available on the efficacy of screening these diversions (Moyle and Israel 2005, p. 20). Water diversions are primarily located on the edge of channels and along river banks. Delta smelt are a pelagic fish species and tend to occupy the middle of the channel and the middle of the water column, where they are unlikely to be vulnerable to entrainment into these diversions.

Power Plant Diversions: GenOn retired one (Contra Costa Generating Station) of its two power stations within the range of the delta smelt in 2013 (NRG 2013, no pagination). Therefore, this analysis will only consider the other (Pittsburg) power station when assessing threats. The Army Corps of Engineers (Corps) is currently in consultation with the Service for the GenOn Energy Project. The project includes operation and dredging activities at the Antioch plant. The Pittsburg Generating Station in Pittsburg is located on the shoreline of the Sacramento River and San Joaquin River confluence and utilizes once-through-cooling for its generators. As part of a settlement agreement with the Coalition for a Sustainable Delta, the Army Corps and GenOn (the applicant) agreed to reinitiate consultation with the Service for project effects to delta smelt. Power plant operations have been substantially reduced since the late 1970s, when high entrainment and impingement were documented (CDFG 2009, p. 24); the power plant is now either kept offline or operating at very low levels, except as necessary to meet peak power needs. From 2007–2010, capacity utilization of both the currently functioning and recently retired units averaged only 2.3 percent of maximum capacity. The Service is currently working closely with the project applicant and the Corps to address additional information needs related to the project's entrainment influence on delta smelt. Once the additional information is received, the Service will complete the section 7 consultation for the project.

Water Export Facilities: Four major water diversion facilities exported between 4.85 and 8.7 km^3 (3.93 and 7.05 million acre-feet) per year from the Delta during the years 1995 through 2005 (Kimmerer and Nobriga 2008, p. 2). Of these, the State and Federal facilities exported between 4.7 and 8.4 km^3 (3.81 and 6.81 million acre-feet) per year. Operation of water export facilities directly affects fish by entrainment into the diversion facility. The risk of entrainment varies with the environmental and manmade effects on Delta hydrology and the location of delta smelt in the Delta (Culberson *et al.* 2004, pp. 260–262; Kimmerer and Nobriga 2008, pp. 19–20).

Entrainment of delta smelt varies among seasons and among years. Studies of entrainment at the State and Federal export facilities found that entrainment rates increased with reverse flows in the Delta, which are related to export rates (Kimmerer 2008, p. 20–22). The entrainment of adult delta smelt at Jones and Banks occurs mainly during their upstream spawning migration between December and April (Grimaldo *et al.* 2009). Most salvage of juvenile delta smelt occurs from April-July with a peak in May-June (Grimaldo *et al.* 2009). Kimmerer (2008, p. 20, 22) estimated that from 0 to 62 percent of the larval population and 3 to 50 percent of the adult population is entrained annually by the State and Federal export facilities. Although an effort is made to salvage fish entrained by the pumping facilities, delta smelt are too fragile to do so effectively, and essentially all delta smelt entrained by the pumping facilities, including all delta smelt that enter the SWP's Clifton Court Forebay, do not survive (Bennett 2005, p. 37).

Entrainment may also affect the distribution of the successfully spawned population. Export of water by the CVP and SWP likely limits the reproductive success of delta smelt in the San Joaquin River by entraining most larvae during downstream transport from spawning sites to rearing areas (Kimmerer and Nobriga 2008, p. 11). Winter entrainment of delta smelt represents a loss of pre-spawning adults and their reproductive potential (Sommer *et al.* 2007).

The population-level effects of such losses are unknown. However, increases in winter salvage of adults at the State and Federal export facilities during the early 2000s coincide with declines in delta smelt abundance estimates during the same time period (Baxter *et al.* 2008, p.18). The total annual pumping from the State and Federal export facilities increased significantly in 2000, and has remained above 1990's levels through 2007 (USFWS 2008, p. 125). The delta smelt Fall Midwater Trawl (FMWT) abundance index decreased in the year 2000, and experienced severe declines two years later (CDFG 2008, p. 2). While there are many factors contributing to the declining trend in delta smelt abundance estimates, we consider entrainment by State and Federal water export facilities to be a significant and ongoing threat to the delta smelt.

We consider entrainment to be a threat to delta smelt. The operation of State and Federal export facilities constitute an ongoing threat to delta smelt through direct mortality by entrainment. We do not consider entrainment by agricultural diversions to be a significant threat due to their nearshore location. Entrainment into Pittsburgh power plant has had a significant impact on delta smelt in the past; however, their operations have been modified, and further study is needed to determine the present level of threat to delta smelt.

Introduced Species

Introduced species have altered the Delta food web and may have played a role in the decline of delta smelt (Nobriga 1998, p. 20). The overbite clam (*Corbula amurensis*) is a nonnative species that became abundant in the Delta in the late 1980s. Starting in about 1987 to 1988, declines were observed in the abundance of phytoplankton (Alpine and Cloern 1992, p. 951) and the copepod *Eurytemora affinis.* These declines have been attributed to grazing by the overbite clam (Kimmerer *et al.* 1994, p. 86). The overbite clam competes with delta smelt for copepod nauplii (Nobriga and Herbold 2008, p. 23). It is unknown how intensively overbite clam grazing and delta smelt directly compete for food, but overbite clam consumption of shared prey resources does have other ecosystem consequences that appear to have affected delta smelt indirectly. It is believed that these changes in the estuarine food web negatively influence pelagic fish abundance, including delta smelt abundance. Recent studies suggest that summer food limitation remains a major stressor on Delta smelt (Baxter *et al.* 2010, p. 57).

Copepods (*E. affinis*, *Psuedodiaptomus forbesi*), a major prey item for delta smelt, have declined in abundance in the Delta since the 1970s (Kimmerer and Orsi 1996, p. 409). *Limnoithona tetraspina* (no common name) is a nonnative copepod that began increasing in numbers in the delta in the mid-1990s – about the same time that the delta smelt's preferred prey copepod, *P.*

forbesi, began declining (Bennett 2005, p. 18). *L. tetraspina* is now the most abundant copepod species in the low salinity zone (Bouley and Kimmerer 2006, p. 219), and is likely an inferior prey species for delta smelt because of its smaller size and superior predator avoidance abilities when compared to *P. forbesi* (Bennett 2005, p. 18; Baxter *et al.* 2008, p. 22).

It has been hypothesized that delta smelt are adversely affected by competition from other introduced fish species that use overlapping habitats, including Mississippi silversides, (Bennett 2005, pp. 49, 50) striped bass, and wakasagi (Sweetnam 1999). Laboratory studies show that delta smelt growth is inhibited when reared with Mississippi silversides (Bennett 2005). Delta smelt and Mississippi silversides have similar morphology, diet, and lifespan, but silversides have a broader diet, and a generally wider ecological niche, a pattern that could give it a competitive advantage over delta smelt. However, there is no empirical evidence to support the conclusion that competition between these species is a factor that influences the abundance of delta smelt in the wild (Bennett 2005, p. 50). Introduced Mississippi silversides as well as striped bass and largemouth bass do predate delta smelt and discussions on predation can be found in the **Disease or Predation** section above.

Egeria densa and other non-native submerged aquatic vegetation (e.g., *Myriophyllum spicatum*) can affect delta smelt in direct and indirect ways. Directly, submerged aquatic vegetation can overwhelm littoral habitats (inter-tidal shoals and beaches) where delta smelt may spawn, making them unsuitable for spawning. Indirectly, submerged aquatic vegetation decreases turbidity by trapping suspended sediment, which has contributed to a decrease in both juvenile and adult smelt habitat quality (Feyrer *et al.* 2007; Nobriga *et al.* 2008). Increased water clarity may delay feeding and may also make delta smelt more susceptible to predation pressure.

In summary, we find that introduced species including the overbite clam have altered the Delta food web and constitute a threat to delta smelt. It is likely that impacts to delta smelt from introduced species will continue and may increase in the future as additional species are introduced into the Delta

Contaminants

In 2009, over 15 million pounds of pesticides were applied within the five-county Bay-Delta area and Bay-Delta waters are listed as impaired for several legacy and currently used pesticides under the Clean Water Act section 303(d) (California Department of Pesticide Regulation 2011, p. 1). Concentrations of dissolved pesticides vary in the Delta both temporally and spatially (Kuivila 2000, p. 1). Several areas of the Delta, particularly the San Joaquin River and its tributaries, are impaired due to elevated levels of diazinon and chlorpyrifos, which are toxic at low concentrations to some aquatic organisms (MacCoy *et al.* 1995, pp. 21–30). Several studies have demonstrated the acute and chronic toxicity of two common dormant-spray insecticides, diazinon and esfenvalerate, in fish species (Barry *et al*. 1995, p. 273; Goodman *et al*. 1979, p. 479; Holdway *et al*.; 1994, p. 169; Scholz *et al*. 2000, p. 1911; Tanner and Knuth 1996, p. 244).

Pyrethroid pesticides are of particular concern because of their widespread use, and their tendency to be genotoxic (DNA damaging) to fishes at low doses (in the range of micrograms per liter) (Campana *et al.* 1999, p. 159). The pyrethroid esfenvalerate is associated with delayed spawning and reduced larval survival of bluegill sunfish (*Lepomis macrochirus*) (Tanner and

Knuth 1996, pp. 246–250) and increased susceptibility of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) to disease (Clifford *et al.* 2005, pp. 1770–1771). In addition, synthetic pyrethroids may interfere with nerve cell function, which could eventually result in paralysis (Bradbury and Coats 1989, pp. 377–378; Shafer and Meyer 2004, pp. 304–305). Weston and Lydy (2010, p. 1835) found the largest source of pyrethroids flowing into the Delta to be coming from the Sacramento Regional Wastewater Treatment Plant (SRWTP), where only secondary treatment occurs. Their data not only indicate the presence of these contaminants, but the concentrations found exceeded acute toxicity thresholds for the amphipod *Hyalella azteca*. This is of substantial concern because the use of insecticides in the urban environment had not before been considered the primary source of insecticides flowing into the Delta. Furthermore, this was not the case for the Stockton Wastewater Treatment facility, where tertiary treatment occurs, suggesting that different treatment methods may remove or retain pyrethroids differently (Baxter *et.al.* 2010, p. 33).

Ammonia loading in the Bay-Delta has increased significantly in the last 25 years (Jasby 2008, p. 15-16). Effects of elevated ammonia levels on fish range from irritation of skin, gills, and eyes to reduced swimming ability and mortality (Wicks *et al*. 2002, p. 67). Delta smelt have shown direct sensitivity to ammonia at the larval and juvenile stages (Werner *et al*. 2008, pp. 85–88). Connon *et al.* (2011, pp. 347-375) investigated the sublethal effects of ammonia exposure on the genes of juvenile delta smelt and found that ammonia altered gene transcription including specific genes related to cell membrane integrity, energy metabolism, and cellular responses to environmental stimuli. The study supports the possibility of ammonia exposure-induced cell membrane destabilization that would affect membrane permeability and thus enhance the uptake of other contaminants. Ammonia also can be toxic to several species of copepods important to larval and juvenile fishes (Werner *et al*. 2010, pp. 78–79; Teh *et al*. 2011, pp. 25–27).

In addition to direct effects on fish, ammonia in the form of ammonium has been shown to reduce primary production by inhibiting nitrate uptake and suppressing spring phytoplankton blooms in Suisun and Grizzly Bays (Dugdale *et al.* 2007, pp. 26–28). The role of ammonium nitrogen uptake inhibition in Sacramento River primary production is less certain than in the Bays. Parker *et al.* (2012, pp. 577–580) observed primary production in the Sacramento River decreased in the SRWTP region as compared to the upper river region during the months of March and April. However, a previous study found that chlorophyll declines above the SRWTP between the Tower Bridge in Sacramento and Garcia Bend (Foe *et al.* 2010, p. 13). The application of general ecological principles would lead us to believe that decreased primary productivity, wherever it occurs in Delta smelt habitat, is likely to lead to a decrease in copepods and other zooplankton that delta smelt rely upon for food. A link between primary productivity and productivity in higher trophic levels has been documented in various pelagic food webs (Nixon 1988, Sobczak *et al*. 2005), although it has not been shown specifically in the San Francisco Bay-Delta. Kimmerer 2008 (p. 24) showed a statistically significant relationship between juvenile delta smelt survival and zooplankton biomass over the long term.

The EPA evaluated the risks of diazinon use on agriculture and nursery stock for delta smelt and tidewater goby (*Eucyclogobius newberryi*) (USEPA 2012, pp. 17–18). The assessment determined that diazinon use was "likely to adversely affect" both fish species. EPA also identified the potential for acute and chronic indirect effects to aquatic prey items, aquatic habitat or primary productivity. Additionally, EPA determined that there was the potential for modification of the designated critical habitat from use of the chemical (USEPA 2012, pp. 17–18).

Selenium, introduced into the estuary primarily from agricultural irrigation runoff via the San Joaquin River drainage and oil refineries, has been implicated in toxic and reproductive effects in fish and wildlife (Baxter 2010 *et al.*, p. 28; Linville *et al*. 2002, p. 52). Selenium exposure has been shown to have effects on some benthic foraging species; however, there is no evidence that selenium exposure is contributing to the decline of delta smelt or other pelagic species in the Bay-Delta (Baxter *et al*. 2010, p. 28).

Large blooms of toxic *Microcystis aeruginosa* (blue-green algae) were first documented in the Bay-Delta during the summer of 1999 (Lehman *et al*. 2005, p. 87). *M. aeruginosa* forms large colonies throughout most of the Delta and increasingly down into eastern Suisun Bay (Lehman *et al*. 2005, p. 92). Blooms typically occur when water temperatures are above 20 °C (68 °F) (Lehman *et al.* 2005, p. 87). Preliminary evidence indicates that the toxins produced by local blooms are not directly toxic to fishes at current concentrations (Baxter *et al.* 2010, p. 10). However, the copepods that delta smelt eat are particularly susceptible to those toxins (Ger 2008, pp. 12, 13; Ger *et al.* 2010, p. 1554). *M. aeruginosa* blooms may also decrease dissolved oxygen to lethal levels for fish (Lehman *et al.* 2005, p. 97). An investigation of food web effects and fish toxicity concluded that even at low abundances, *M. aeruginosa* may impact estuarine fish productivity through both toxicity and food web impacts (Lehman *et al.* 2010, p. 241–245). *M. aeruginosa* is most likely to affect delta smelt adults and larvae directly during blooms in late spring when delta smelt are present in the Delta for spawning. Early fall blooms may have less impact as they occur when the majority of delta smelt are located downstream in the LSZ.

Vulnerability of Small Populations

Delta smelt are relatively concentrated in their rearing habitat during the fall, making them vulnerable to environmental conditions such as droughts, contaminant spills, and predation. Small, isolated populations are more likely to lose genetic variability due to genetic drift (random genetic changes over time), and to suffer inbreeding depression due to the fixation of deleterious alleles (gene variants) (Lande 1999, pp. 11–17). Populations at low densities are often subject to allele effects, which involve decreases in the ratio of offspring to adults as the population density decreases (Dennis 2002, p. 389). It is unknown if small population size may have contributed to delta smelt's decline.

Summary for Factor E

Based on a review of the best scientific and commercial information available, we find that the following additional natural or manmade factors pose ongoing threats to the delta smelt: entrainment by the State and Federal water export facilities and introduced species. Ammonia in the form of ammonium may also constitute a threat to the delta smelt. Additional threats are entrainment into power plant diversions, contaminants, and small population effects.

CONSERVATION MEASURES PLANNED OR IMPLEMENTED

The CALFED Ecosystem Restoration Program (ERP) developed a strategic plan for implementing an ecosystem-based approach for achieving conservation targets (CALFED 2000a, pp. 1–3). The CDFG is the primary implementing agency for the ERP. The goal of ERP in improving conditions for delta smelt will carry forward, irrespective of the species Federal listing status. CALFED had an explicit goal to balance the water supply program elements with the restoration of the Bay-Delta and tributary ecosystems and recovery of the delta smelt and other species. Because achieving the diverse goals of the program is iterative and subject to annual funding by diverse agencies, the CALFED agencies have committed to maintaining balanced implementation of the program within an adaptive management framework. The intention of this framework is that the storage, conveyance, and levee program elements would be implemented in such a way that the delta smelt's status would be maintained and eventually improved.

The Bay-Delta Conservation Plan (BDCP), an effort to help provide restoration of the Bay-Delta ecosystem and reliable water supplies, is currently in preparation by a collaborative of water agencies, resource agencies, and environmental groups. The BDCP is intended to provide a basis for permitting take of listed species under sections 7 and 10 of the Act and the California Natural Communities Conservation Planning Act, and would provide a comprehensive habitat conservation and restoration plan for the Bay-Delta, as well as a new funding source. The BDCP shares many of the same goals outlined in the 2000 CALFED Record of Decision (CALFED 2000) but would not specifically address all listed-species issues. The BDCP would, however, target many of the threats to current and future listed species and could contribute to species recovery. Delta smelt is a covered species under BDCP. However, the BDCP, if completed, would not be initiated until at least 2013 or later. The plan's implementation is anticipated to extend through 2060.

SUMMARY OF THREATS

We conclude that the greatest threats to delta smelt are entrainment by State and Federal water export facilities (Factor E); summer and fall increases in salinity, summer and fall increases water clarity (Factor A), and effects from introduced species (Factor E). Ammonia in the form of ammonium (Factor E) may also constitute a significant threat to the delta smelt. Additional threats include predation (Factor C), entrainment into power plants (Factor E), contaminants (Factor E) and small population size (Factor E). Existing regulatory mechanisms (Factor D) have not proven adequate to halt the decline of delta smelt since the time of listing as a threatened species. We are unable to determine with certainty which threats or combinations of threats are directly responsible for the decrease in delta smelt abundance. However, the apparent low abundance of delta smelt in concert with ongoing threats throughout its range indicates that the delta smelt is now in danger of extinction throughout its range.

Recommended Conservation Measures

Increasing Delta outflows so that they more closely approximate unimpaired flows in the watershed would address several needs of the longfin smelt, likely improving habitat quality and quantity. Furthermore, increased winter and spring flows may reduce water clarity, which would increase habitat quality for longfin smelt. Contaminant reduction within the Bay-Delta could improve primary productivity while at the same time limiting toxicity exposure to longfin smelt. Reducing ammonia concentrations from the Sacramento Waste Water Treatment Plant may help to increase primary productivity within the Bay-Delta, resulting in better longfin smelt growth and survival. The reduction of pesticides entering the Delta could also improve habitat conditions. Therefore, the FWS recommends the reduction of contaminants entering the estuary.

LISTING PRIORITY

<table>
<tr><td>Magnitude</td><td>Immediacy</td><td>Taxonomy</td><td>Priority</td></tr>
<tr><td rowspan="6">High</td><td rowspan="3">Imminent</td><td>Monotypic genus</td><td>1</td></tr>
<tr><td>Species</td><td>2</td></tr>
<tr><td>Subspecies/Population</td><td>3</td></tr>
<tr><td rowspan="3">Non-imminent</td><td>Monotypic genus</td><td>4</td></tr>
<tr><td>Species</td><td>5</td></tr>
<tr><td>Subspecies/Population</td><td>6</td></tr>
<tr><td rowspan="6">Moderate to Low</td><td rowspan="3">Imminent</td><td>Monotype genus</td><td>7</td></tr>
<tr><td>Species</td><td>8</td></tr>
<tr><td>Subspecies/Population</td><td>9</td></tr>
<tr><td rowspan="3">Non-Imminent</td><td>Monotype genus</td><td>10</td></tr>
<tr><td>Species</td><td>11</td></tr>
<tr><td>Subspecies/Population</td><td>12</td></tr>
</table>

Rationale for listing priority number:

Magnitude:

The magnitude of threats is high due to a number of ongoing threats. These threats include salinity and turbidity changes, entrainment and invasive species. Ammonia in the form of ammonium may also be a significant threat to the survival of the delta smelt. The ecology and biology of the San Francisco Bay-Delta has changed drastically over the last 100 years. Although a number of conservation measures have been put in place to protect the delta smelt and its habitat, the population continues to decline. Turbidity changes due to levees and dams and increased ammonium concentrations have taken place throughout the range of the delta smelt. Changes in the position of the low salinity zone in the Bay-Delta have altered foraging and breeding habitat. Although this threat does not extend throughout the range of the delta smelt, it does encompass areas that are key to the delta smelt's survival, including Suisun Marsh and Suisun Bay. Delta smelt numbers have dwindled to a fraction of what they were before these changes took place. Stress from water pumping operations and invasive species is expected to continue into the future as water demands for an ever growing population in California continue to grow.

Imminence

The threats discussed above are ongoing and likely to continue into the future. We therefore consider threats to be imminent.

Have you promptly reviewed all of the information received regarding the species for the purpose of determining whether emergency listing is needed? Yes

Is Emergency Listing Warranted? No

DESCRIPTION OF MONITORING

The Interagency Ecological Program (IEP) was created by State and Federal resource agencies to focus scientific inquiry on Delta issues. The IEP initiated the Pelagic Organism Decline (POD) study effort in 2005 to focus scientific effort and resources on the most recent and precipitous declines in abundance of several species, including delta smelt. Delta smelt are regularly captured in monitoring surveys. IEP research includes effects of contaminants, invasive species, export pump entrainment and freshwater outflow on delta smelt biology. Species experts from universities, State and Federal Governments, and non-profits work cooperatively to yield crucial information on the status of the species through the IEP program. Although the focus of its studies and the level of effort have changed over time, in general, their surveys have been directed at researching the Pelagic Organism Decline in the Bay-Delta which includes the decline of the Delta smelt. The Service funds a delta smelt research biologist position at the Stockton Fish and Wildlife Office to investigate potential threats to the species. Exiting funding comes from the Service and from CalFed agencies through grants from the CalFed Science Program. The Service is presently cooperating with scientists from the University of California-Davis and the California Department of Water Resources to develop a genetic refuge population of delta smelt and a Delta smelt culture facility. Currently funded IEP research includes studies in delta smelt feeding and foodweb interactions, monitoring inter-annual variability of delta smelt population contingents and growth, delta smelt genetics, delta smelt culture facility, modeling delta smelt population in the SF Estuary, influence of water quality and SAV on LMB distribution, diet composition and predation on delta smelt, hydrodynamic and particle tracking modeling of delta smelt habitat and prey, development of an acoustic transmitter suitable for use in delta smelt, evaluation of natural marking in delta smelt and longfin smelt , potential loss of life history variation and the decline of delta smelt, patterns of predation on larval delta smelt (IEP 2011, pp. 1-5).

Figure 1: Monitoring surveys from which Delta smelt abundance trends are derived.

Survey	Agency Lead	Target Species	Season of Sample	Frequency	Application of Data
Spring Kodiak Trawl (SKT)	CDFG	Delta smelt	Jan-May	Monthly	Adult spawning survey, distribution and relative abundance
Smelt Larva Survey (SLS)	CDFG	Longfin Smelt*	Jan-March	Biweekly	Distribution and relative abundance
20mm Survey	CDFG	Delta smelt	March-July	Biweekly	Larval-juvenile survey, distribution and relative abundance
Summer Townet Survey (TNS)	CDFG	Striped Bass**	June-Aug	Biweekly	Distribution and relative abundance
Fall Midwater Trawl (FMWT)	CDFG	Striped Bass**	Sept-Dec	Monthly	Annual delta smelt abundance index calculation

*** The SLS was originally a delta smelt-targeted pilot study, with a study design that changed from year to year. In 2009, the SLS was redesigned to collect longfin smelt distribution data for the purpose of providing recommendations for water operations in the Delta.**

**** The FMWT and TNS were originally implemented to monitor distribution and abundance of striped bass. Because these surveys also collected information on the distribution and abundance of delta smelt, they are both mandated by USFWS in its state and federal water operations BO.**

COORDINATION WITH STATES

The Delta smelt is known only from California. Therefore, coordination is done with the state of California. Much of the coordination is done through the Interagency Ecological Program and includes research and abundance surveys (See Description of Monitoring above).

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APPROVAL/CONCURRENCE: Lead Regions must obtain written concurrence from all other Regions within the range of the species before recommending changes, including elevations or removals from candidate status and listing priority changes; the Regional Director must approve all such recommendations. The Director must concur on all resubmitted 12-month petition findings, additions or removal of species from candidate status, and listing priority changes.

Approve: 5/30/2013

Regional Director, Fish and Wildlife Service Date

10/28/2013

Concur: ___________________________

Director, Fish and Wildlife Service Date

Do not concur: ___________________________

Director, Fish and Wildlife Service Date

Director's Remarks:

Date of annual review: April 15, 2012

Conducted by: Colin Grant